# Autonomous AI Agents for Spacecraft Operations

Technical Proposal

December 7, 2024

## Contents

# 1 Introduction

The current state of spacecraft operations heavily relies on human intervention for decision-making and control. This dependency introduces significant delays and inefficiencies, particularly in deep space missions where communication latency can be substantial. The integration of Artificial Intelligence (AI) into spacecraft operations presents a transformative opportunity to enhance autonomy, efficiency, and decision-making capabilities. AI can optimize mission trajectories, enable real-time decision-making, and reduce the need for constant human oversight.

The primary goal of the Autonomous AI Agents for Spacecraft Operations project is to integrate AI systems into various aspects of spacecraft operations, including image processing, instrument control, and satellite navigation. This integration aims to reduce human intervention, optimize mission trajectories, and enable real-time decision-making, thereby improving mission efficiency and reducing communication delays.

The project anticipates a growing role for AI in space missions, supported by collaborations with organizations like NASA and Carnegie Mellon University. It aims to address technical, ethical, and legal challenges, including explainability and certification. Rigorous testing and validation processes will ensure the reliability and safety of AI systems, while human operators will maintain a "human-on-the-loop" role to ensure trusted autonomy. Data security and privacy will be prioritized through secure communication protocols and data encryption.

# 2 Project Objectives and Scope

The project has several detailed objectives, including reducing human intervention in spacecraft operations and optimizing mission trajectories. The scope of the project encompasses the integration of AI in various spacecraft operations such as image processing and satellite navigation. The anticipated outcomes include enhanced mission efficiency, reduced communication delays, and increased return on investment for space missions.

The project will leverage partnerships and collaborations to support the development and deployment of AI agents, ultimately enhancing our understanding of the universe and facilitating future space exploration initiatives.

# 3 Architecture of AI Systems in Spacecraft

The architecture of AI systems in spacecraft involves a distributed setup with chips, microcontrollers, and microprocessors spread across several boards or subsystems. This distributed architecture allows for specialized tasks to be handled by specific units, while a few central units manage overall spacecraft operations.

## 3.1 Mission and System Budget Definition

The mission and system budget definition includes parameters such as mass, link, power, and delta-V. These parameters are critical for defining the component list and mission architecture. The optimization of the internal configuration involves considering volumes and specific component requirements, such as positioning inside the spacecraft.

## 3.2 Optimization of Internal Configuration

The optimization of the internal configuration is achieved through algorithms that evaluate various configurations to maximize efficiency and performance. This involves defining a power budget and a list of operative modes, which can be automatically computed for solar panel and battery sizing.

# 4 Mission Design and Planning

Mission design and planning involve exploring different mission architectures, including CubeSat missions and multi-spacecraft missions. The advantages of constellation over monolithic missions are considered, along with mission and system budget constraints and optimization strategies.

# 5 Technical, Ethical, and Legal Challenges

The project addresses several technical challenges, such as the explainability and certification of AI systems. Ethical considerations in AI decision-making are also crucial, with a focus on maintaining a "human-on-the-loop" role. Legal compliance with international space regulations and standards is ensured through rigorous testing and accountability measures.

# 6 Testing and Validation

Rigorous testing and validation processes are essential to ensure the reliability and safety of AI systems. Data security and privacy are prioritized through secure communication protocols and data encryption.

# 7 Partnerships and Collaborations

Collaborations with organizations like NASA and Carnegie Mellon University play a significant role in advancing AI technologies for space exploration. These partnerships support the development and deployment of AI agents, enhancing the project's impact and reach.

# 8 Conclusion

The integration of AI into spacecraft operations is expected to significantly increase the return on investment for space missions. The project aims to enhance our understanding of the universe and facilitate future space exploration initiatives. The future prospects for AI in space exploration are promising, with potential for further advancements and innovations.